

*PROXIMA CENTAURI AS A FLARE STAR*

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1. The dwarf red companion of the bright double star Alpha Centauri was detected by Innes in the course of an examination of plates made with the Franklin Adams camera at the Union Observatory, Johannesburg, in 1915.<sup>1</sup> Although the object was two degrees distant from Alpha Centauri, its similar motion, and subsequently its comparable parallax, clearly showed the physical association of the three objects. The somewhat larger proper motion and the slightly larger parallax, derived by some of the observers, have led to the conclusion that Proxima Centauri is actually a little nearer than Alpha Centauri, and is therefore the nearest of all stars so far discovered; hence the appropriateness of its name. The difference in the parallax, however, scarcely exceeds the probable error of the determinations, and van de Kamp gives in his listing of the stars nearer than five parsecs<sup>2</sup> identical values for the parallax,  $0''.761$ , and for the annual proper motion of Alpha,  $3''.68$ , and of Proxima,  $3''.85$ .

2. It became clear some years ago that such low-luminosity red dwarfs, at the faintest end of the main sequence, are not simple and quietly perishing stars. Castor C, for example, was found at Mount Wilson to be a close pair of dwarf Class M stars. It is an eclipsing variable with a period of 0.814 days. Later, in the course of his parallax and proper motion work, van Maanen found that Lalande 21258B and Ross 882 had each shown one abnormal brightening among the many images appearing on the Mount Wilson plates.<sup>3</sup>

In 1949, Luyten's remarkable double, L 726-8, discovered by him as a large proper motion star on the Harvard Bruce plates, was found to be a light variable. Not only is it one of the nearest of all stars, and among the dimmest stellar radiators yet on record, but also the fainter component of the pair showed brief flares on two occasions. The star has been fully discussed by Luyten.<sup>4</sup> In their concurrent work on the spectra, Joy and Humason<sup>5</sup> also found a flare, especially strong in blue light. Subsequently 569 Harvard plates yielded seven additional flares,<sup>6</sup> one of them corresponding to a momentary increase of forty times in the light intensity. The results for L 726-8 not only gave support to van Maanen's earlier observations, but attracted general attention to the dwarf red stars. There are not many of them on record, and they cannot be seen very deep in space; but here were three affected by temporary flashes—a novelty in the photometry of stars. The spectrum of Luyten's star showed unusual charac-

teristics, including bright calcium and hydrogen lines.<sup>6</sup> Obviously these red stars are not cooling off monotonously.

The list was increased to four by the interesting photoelectric discovery and observation by Gordon and Kron of an hour-long flaring-up of the M dwarf, BD + 20°2465, which confirmed earlier evidence for the other flare stars that the duration of the spurt and recovery in brightness is indeed of short duration.<sup>7</sup>

3. Before any of the foregoing information on flare stars had become known, nearly a hundred Harvard photographs of the field of Proxima Centauri had been examined in search of variability of the continuous sort that affects the dwarf red variable of the Castor system. The results were negative. The constant photographic magnitude was established, with the aid of the most convenient magnitude sequence, as 13.4, with small dispersion around that value except for one very discordant measure which was ignored. When Thackeray recently published a discussion of the variable spectrum of Proxima<sup>8</sup> and reported also that the observers at the Cape Observatory had examined 58 plates of the star, taken for parallax during the past two decades, and found no certain evidence of flares, the earlier Harvard measures were reexamined and the one most discordant observation was recognized as a probable flare. Four measures of 13.2, 13.2, 13.0, and 13.2 possibly also indicate flare phenomena, and are included in the later tabulation. The plates had been made with the 10-inch Metcalf on a neighboring Milky Way Field, No. 171, and Proxima is in a rather unsatisfactory position on the photographs.

An examination of several series in the Harvard plate collection has now been undertaken. The MF plates were searched by Miss C. D. Boyd and the other series by Mrs. V. McK. Nail. Without going further back than 1925, five hundred additional plates were found on which the image of Proxima Centauri appears. The following tabulation gives the plate series, name of telescope, the average exposure time, the number of plates examined, and the number of times that Proxima Centauri was found to be of magnitude 12.8 or brighter.

MF	Metcalf triplet	45 min.	93 plates	1 flare
B	Bache doublet	45	80	6
RB	Ross-Fecker lens	90	170	15
AM	Cooke lens	90	211	19
AX	Tessar lens	120	35	7
A	Bruce doublet	120	3	0
Total			592	48

It appears that on eight per cent of the plates (six per cent of the exposure time) the star was brighter than average by a distinctly measurable amount, making it the most active flare star on record. By going to the older

Harvard plates the list of recorded flares could be substantially increased. Possibly such a study should be made if it later appears that there is an indication of periodicity in the outbursts, but at present it is more important to follow some of these flares carefully with photoelectric photometers or short exposure photographs in order to learn more about the nature of the outbursts than can be obtained from these long-exposure Harvard plates. Proxima has now been put on the program of the photoelectric photometer at the Harvard station in South Africa.

For all series the exposures are so long that brief sharp maxima are much smoothed out. The brightest recorded maxima are 12.4, indicating amplitudes of at least one magnitude. The AX camera has a steep color curve and is not very reliable for work on such red stars.

On three nights consecutive exposures were made throughout 5.5, 2.25, and 7 hours with the 10-inch Metcalf telescope. No measurable change of brightness was shown. In addition, on seven nights plates with different instruments are available. Four pairs occur at times of flares; they give magnitudes consistent with the presumption of outbursts of an hour or so.

The Julian Day and decimal of a day for the flares on MF, B, RB, AM, and AX plates, with magnitude estimates by Mrs. Nail, are as follows:

JD AND GMT	SERIES	MAG.	JD AND GMT	SERIES	MAG.	JD AND GMT	SERIES	MAG
2423996.534	AX	12.6	2428040.215	B	12.6	2431184.427	AM	12.7
24244.827	AX	12.5	28276.553	RB	12.8	31197.562	B	12.8
24286.694	AX	12.4	28283.542	B	12.8	31311.343	AM	12.6
24294.693	AX	12.7	28289.417	AM	12.4	31330.264	AM	12.8
25446.285	AX	12.4	28896.552	AM	12.3	31494.591	AM	12.5
26091.372	MF	12.6	28994.495	AM	12.6	31584.310	B	12.7
26091.422	RB	12.9	29051.408	AM	12.8	31614.414	AM	12.8
26131.331	MF	13.2	29131.238	RB	12.8	31620.287	AM	12.8
26181.242	MF	13.2	29834.345	AM	12.4	31873.323	AM	12.4
26189.286	RB	12.4	29850.233	RB	12.8	31887.529	AX	12.6
26215.220	MF	13.0	30134.463	AM	12.8	31921.424	AM	12.8
26812.531	RB	12.8	30474.446	RB	12.8	31935.410	RB	12.8
27519.505	AX	12.4	30491.354	AM	12.6	32033.290	AM	12.7
27525.635	MF	13.2	30497.277	B	12.7	32324.277	B	12.6
27630.224	RB	12.6	30515.448	RB	12.6	32387.291	AM	12.6
27958.469	RB	12.8	30578.289	AM	12.7	32406.227	AM	12.6
28010.320	RB	12.8	30850.451	RB	12.8	33033.577	RB	12.8
			30900.320	RB	12.4			

4. A sixth star of spectral Class M, which has the spectrum characteristics of SS Cygni, may be assignable to this small group of flare stars. It is AE Aquarii, which has been studied at various observatories and is now on the program of the American Association of Variable Star Observers.<sup>9</sup> Recent unpublished observations show rapid changes in the course of an hour or so. Like Proxima Centauri, it merits study with photoelectric photometers and high-speed spectrographs.

5. Dwarf red flare stars may become of considerable importance in considerations of stellar evolution. Something near one-half of the fifty nearest stars now known are dwarfs of Class M, with absolute photographic magnitudes fainter than +12. Of these, about twenty per cent are now known to be affected with sudden bursts of radiation, presumably emanating, as Gordon and Kron, Whipple, Greenstein<sup>10</sup> and others have pointed out, from relatively small areas which for a time explode with highly intense (blue) radiation, and quickly cool to the average conditions.

The great contrast in surface brightness between the intense blue outburst and the relatively cool surrounding surface greatly increases the total light of the red dwarf stars, whereas similar phenomena on the surface of the sun, or on stars of earlier spectral class, would not appreciably affect the total radiation. The total energy of an outburst on Proxima is equivalent to that of some of the solar flares currently observed; and although the solar flares do not measurably increase the magnitude of the sun, they do succeed in disturbing the earth's ionosphere.

6. Is it likely that measurable eruptive flaring disturbs the radiation of all the red dwarf stars? Possibly the phenomenon is universal, especially for red dwarfs with emission spectra, but the examination of 225 Harvard plates of the RB, RH and BM series on Barnard's Star (spectrum M 6, absolute magnitude +13.4, vis.) reveals no variability.

<sup>1</sup> Innes, R. T. A., *Union Obs. Circ.*, **30** (1915), and **40** (1917).

<sup>2</sup> van de Kamp, P., *Pop. Ast.*, **48**, 297 (1940).

<sup>3</sup> van Maanen, A., *Mt. Wilson Contr.*, **630** (1940); *Ap. J.*, **91**, 503 (1940); *Pub. Astr. Soc. Pac.*, **57**, 216 (1945).

<sup>4</sup> Luyten, W. J., *Ap. J.*, **109**, 532 (1949).

<sup>5</sup> Joy, A. H., and Humason, M. L., *Pub. Astr. Soc. Pac.*, **61**, 133 (1949).

<sup>6</sup> *Harv. Ann. Card.*, 1010 (July 1949).

<sup>7</sup> Gordon, K. C., and Kron, G. E., *Pub. Astr. Soc. Pac.*, **61**, 210 (1949).

<sup>8</sup> Thackeray, A. D., *Mon. Not.*, **110**, 45 (1950).

<sup>9</sup> Campbell, L., *Pop. Ast.*, **55**, 557 (1947).

<sup>10</sup> Greenstein, J., *Pub. Astr. Soc. Pac.*, **62**, 160 (1950).